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Specification

[Claims]

[Claim 1] An electrophoresis display apparatus having a plurality of pixels, each pixel comprising a first substrate, a first flat electrode provided on the first substrate, a second transparent substrate provided on the first electrode side so as to oppose the first substrate, a dispersion layer interposed between the first and second substrates, containing colorless fluid and at least one kind of electrophoretic particle charged with the same polarity, a covering layer provided at a periphery of a surface of the second substrate on an opposite side of the dispersion layer, and a second electrode provided in a range covered with the covering layer in a region between the first and second substrates.

[Claim 2] An electrophoresis display apparatus according to claim 1, wherein a dielectric layer having color which can form a contrast with color of the electrophoretic particles is provided between the first electrode and the dispersion layer.

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[Claim 3] An electrophoresis display apparatus according to claim 1, wherein the first electrode has color which can form a contrast with color of the electrophoretic particles.

[Claim 4] An electrophoresis display apparatus according to claim 1, wherein the first electrode is transparent, and the first substrate has color which can form a contrast with color of the electrophoretic particles.

[Claim 5] An electrophoresis display apparatus according to claim 1, wherein the first electrode and the first substrate are transparent, and a dielectric layer having color which can form a contrast with color of the electrophoretic particles is provided on a surface of the first substrate on an opposite side of the dispersion layer.

[Claim 6] An electrophoresis display apparatus according to claim 1, further comprising an electrode or an electrode group for limiting a movement region of the electrophoretic particles on the second substrate, in addition to the first and second electrodes.

[Detailed Description of the Invention]

[0001]

[Field of the Invention] The present invention relates to an electrophoresis display apparatus.

[0002]

[Prior Art] In terms of reduction of power consumption or alleviation of burden to the eyes, expectations for a reflection type display apparatus are increasing. Hitherto, as one of reflection type display apparatuses, for example, an electrophoresis display apparatus as described in

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U.S. Patent No. 3,668,106 is known. This electrophoresis display apparatus consists of a dispersion layer, which consists of charged electrophoretic particles and insulating liquid, and a pair of electrodes which sandwiches the dispersion layer. An electric field is applied to the dispersion layer through the electrodes, whereby the electrophoresis particles are moved to the electrode which has an opposite polarity to that of the charged particles, and thus, a display is conducted.

[0003] The above-mentioned insulating liquid, in which a coloring matter is dissolved, has a contrasting color of electrophoretic particles. More specifically, in the case where the electrophoretic particles adhere to the surface of the first electrode closer to an observer, the color of the electrophoretic particles is observed. On the other hand, in the case where the electrophoretic particles adhere to the surface of the second electrode farther away from the observer, the color of the electrophoretic particles is covered with the insulating liquid, and the color of the insulating liquid is observed. As described in Proc. SID, 18, 267 (1977), for example, the electrophoresis display apparatus has the advantages such as a large viewing angle, a high contrast, and low power consumption. However, the electrophoresis display apparatus has the following serious problem: due to the adverse effects such as adsorption of the coloring matter dissolved in the insulating liquid to the electrophoretic particles and invasion of the insulating liquid between the electrode surface to which the electrophoretic particles adsorb and the electrophoretic particles, a high reflectivity, i.e., both brightness and a high contrast cannot be achieved.

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[Problem to be Solved by the Invention] As described above, it was difficult to achieve both brightness and a high contrast in the conventional electrophoresis display apparatus. The present invention has been achieved so as to solve the above-mentioned problem, and its objective is to provide an electrophoresis display apparatus which achieves both brightness and a high contrast.

[0005]
[Means for Solving the Problem]
According to the present invention, an electrophoresis display apparatus having a plurality of pixels is provided, each pixel including a first substrate, a first flat electrode provided on the first substrate, a second transparent substrate provided on the first electrode side so as to oppose the first substrate, a dispersion layer interposed between the first and second substrates, containing colorless fluid and at least one kind of electrophoretic particle charged with the same polarity, a covering layer provided at a periphery of a surface of the second substrate on an opposite side of the dispersion layer, and a second electrode provided in a range covered with the covering layer in a region between the first and second substrates.

[0006]
[Embodiments of the Present Invention] In a display apparatus of the present invention, one pixel includes a pair of substrates and a dispersion layer interposed between the substrates, and the dispersion layer contains colorless fluid and electrophoretic particles having a first color. The periphery of a display surface of the display apparatus is covered with a covering layer, and a second electrode is provided in a region covered with the covering layer. Furthermore, in a region not covered with the covering layer, a

first electrode and a member having a second color which can form a contrast to the first color can be provided.

[0007] According to the present invention, using at least two electrodes segregated by the dispersion layer containing the colorless fluid and the electrophoretic particles having the first color, an electric field which controls a space distribution of the electrophoretic particles in the dispersion layer is applied to the dispersion layer through the electrodes or a group of electrodes, whereby the electrophoretic particles having the first color are contrasted with the member having the second color, and optical reflection characteristics of the dispersion layer can be controlled. As electrodes, a group of at least two electrodes in which a plurality of conductive portions are electrically insulated from each other, as well as a pair of electrodes, can be used.

[0008] In a preferred embodiment of the above-mentioned member, for example, a dielectric layer having a second color which can form a contrast with the color of the electrophoretic particles can be provided between the first electrode and the dispersion layer. In this case, when a voltage is applied in such a manner that the electrophoretic particles having the first color are attracted onto the dielectric layer, the first color is displayed when seen from a second substrate. In contrast, when a voltage is applied in such a manner that the electrophoretic particles are attracted onto the second electrode layer, the electrophoretic particles are covered with the covering layer to become invisible, so that the second color of the dielectric layer is displayed when seen from the second substrate.

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[0009] In another preferred embodiment, for example, as the first electrode, an electrode having a second color which can form a contrast with the color of the electrophoretic particles can be used. In this case, when a voltage is applied in such a manner that the electrophoretic particles having the first color are attracted onto the first electrode, the first color is displayed when seen from the second substrate. In contrast, when a voltage is applied in such a manner that the electrophoretic particles are attracted onto the second electrode layer, the electrophoretic particles are covered with the covering layer to become invisible, so that the second color of the first electrode is displayed when seen from the second substrate.

[0010] In still another preferred embodiment, in the case where the first electrode is transparent, a first substrate having a second color which can form a contrast with the color of the electrophoretic particles can be used. In this case, when a voltage is applied in such a manner that the electrophoretic particles having the first color are attracted onto the first electrode, the first color is displayed when seen from the second substrate. In contrast, when a voltage is applied in such a manner that the electrophoretic particles are attracted onto the second electrode layer, the electrophoretic particles are covered with the covering layer to become invisible, so that the second color of the first substrate is displayed when seen from the second substrate.

[0011] In still another preferred embodiment, in the case where the first electrode and the first substrate are transparent, a dielectric layer having a second color which can form a contrast with the color of the electrophoretic particles can be provided on the surface of the first sub-

strate which is on an opposite side of the dispersion layer. At this time, when a voltage is applied in such a manner that the electrophoretic particles having the first color are attracted onto the dielectric layer, the first color is displayed when seen from the second substrate. In contrast, when a voltage is applied in such a manner that the electrophoretic particles are attracted onto the second electrode layer, the electrophoretic particles are covered with the covering layer to become invisible, so that the second color of the dielectric layer is displayed when seen from the second substrate.

[0012] Furthermore, in another preferred embodiment, in addition to the first electrode and the second electrode, an electrode or a group of electrodes for limiting a movement region of the electrophoretic particles can be further provided on the second substrate.

[0013] Hereinafter, the present invention will be described specifically with reference to the drawings. Figure 1 is a cross-sectional view showing a structure of one pixel portion in an electrophoresis display apparatus of the present invention. Referring to Figure 1, the structure of the present invention will be described below. The electrophoresis display apparatus includes a dispersion layer consisting of electrophoretic particles 8 having a color and transparent fluid 9. The dispersion layer is held in space surrounded by a first substrate 1, a second substrate 2, and a spacer substrate 3 for supporting and sealing a gap between two substrates. In the case of the electrophoresis display apparatus having the structure shown in Figure 1, an observer sees the display apparatus from an outside of the second substrate 2 toward the first substrate, so that the second substrate 2 needs to be transparent. A first elec-

trode 4 is provided on the surface of the first substrate 1 on the dispersion layer side. A second electrode 5 is disposed along the spacer substrate 3. On an outer surface of the second substrate 2, i.e., the surface of the second substrate on an opposite side of the dispersion layer, a covering layer 11 which can sufficiently cover the spacer substrate 3 and the second electrode 5 is provided. The surfaces of the first electrode 4 and the second electrode 5 are covered with dielectric layers 6 and 7, respectively. At least one member of the dielectric layer 6, the first electrode 4, and the first substrate 1 has a contrasting color of the electrophoretic particles 8. An electric circuit 10 applies a voltage to the dispersion layer through the first electrode 4, the second electrode 5, and the dielectric layers 6 and 7, and the level, polarity, and the like of an applied voltage can be freely set.

[0014] In terms of longevity, a contrast, a resolution, and the like of the display apparatus, it is desirable that the electrophoretic particles used in the present invention are stably dispersed in fluid, and have a single polarity and a small particle size distribution. Furthermore, the particle size is preferably in a range of 0.1 µm to 5 µm. When the particle size is in this range, a light scattering efficiency is not decreased, and a sufficient response speed can be obtained under the application of a voltage. As a material for the electrophoretic particles, for example, inorganic pigments such as titanium oxide, zinc oxide, zirconium oxide, ferric oxide, aluminum oxide, cadmium selenide, carbon black, barium sulfate, lead chromate, zinc sulfate, and cadmium sulfide, or organic pigments such as phthalocyanine blue, phthalocyanine green, Hansa yellow, Watchung red, and Dially ride yellow can be used.

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[0015] According to the present invention, it is desirable that fluid for dispersing the electrophoretic particles has small dissolving ability with respect to the electrophoretic particles so as to stably disperse them, contains no ions, and is insulating so as not to generate ions by the application of a voltage. Furthermore, it is preferable that the fluid has substantially the same specific gravity as that of the electrophoretic particles so as to prevent the electrophoretic particles from floating or sinking, and has a low viscosity in terms of mobility of the electrophoretic particles. Examples of insulating liquid which can be used with respect to a relatively number of electrophoresis materials include hexane, decane, kerosene, toluene, xylene, olive oil, tricresyl phosphate, isopropanol, trichlorofluoroethane, dibromotetrafluoroethane, and tetrachloroethylene. In the case where a specific gravity is adjusted in accordance with the electrophoretic particles so as to prevent them from floating or sinking, a mixed fluid can be utilized.

[0016] According to the present invention, a mixing weight ratio of the electrophoretic particles in the dispersion layer is not particularly limited, as long as an electrophoretic property of the electrophoretic particles is not inhibited, and reflection of the dispersion layer can be sufficiently controlled. However, a mixing weight ratio of, for example, 1% by weight to 20% by weight is preferable.

[0017] According to the present invention, in order to increase the charge of the electrophoretic particles or to render the polarity of the electrophoretic particles the same, additives such as a resin and a surfactant can be added to the above-mentioned fluid, if required.

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[0018] According to the present invention, the thickness of the dispersion layer is not particularly limited, as long as the thickness is larger than the diameter of each electrophoretic particle and the movement of the particles are not hindered. However, in order to obtain a high response speed under the application of a voltage, the dispersion layer is desirably as thin as possible. In view of these, the preferable thickness of the dispersion layer is in a range of 5 μm to 200 μm.

[0019] As an electrode material used in the present invention, those with good conductivity such as aluminum, copper, silver, gold, and platinum are preferable. Furthermore, as a transparent electrode material, a thin film of tin oxide, indium oxide, copper iodide, or the like can preferably be used. Furthermore, the electrodes can be formed by an ordinary method such as vapor deposition, sputtering, and photolithography. Furthermore, in the second electrode covered with the covering layer, an uneven structure can be formed on the surface of the electrode so as to increase a surface area to which the electrophoretic particles adsorb. Furthermore, in order to minimize an area of the covering layer and increase an aperture ratio, the spacer substrate and the electrode can be designed in such a manner that a vertical cross-section thereof, i.e., a cross-section in a direction vertical to the first substrate or the second substrate has a semispheric concave portion on the dispersion layer side.

[0020] According to the present invention, material and thicknesses of the spacer substrate and the substrate on which the electrodes are disposed are not particularly limited, as long as a sufficient insulating property and flatness can be maintained, and sufficient strength can be ob-

tained. However, as specific materials, glass, plastic, and ceramic can preferably be used. Furthermore, in the case where the first substrate has a contrasting color of the electrophoretic particles, glass, plastic, or ceramic mixed with an appropriate coloring matter or pigment, or colored ceramic can be used for the substrate.

[0021] According to the present invention, as a dielectric having a contrasting color of the electrophoretic particles disposed on the first substrate, a dielectric which itself has a contrasting color or a dielectric layer mixed with a pigment or dye having a contrasting color can be used.

[0022] Material and thickness of the dielectric layer are not particularly limited, as long as a sufficient voltage is applied to the dispersion layer, and a nonuniform display is avoided. As a material for the dielectric, for example, inorganic substances such as titanium oxide, silicon oxide, and aluminum oxide, or organic substances such as polyethylene, polystyrene, phenol resin, polyamide, polyimide, polypropylene, epoxy resin, polyvinyl chloride, fluorocarbon resin, and silicon resin can be used. In the case where the dielectric layer is mixed with a pigment or dye having a contrasting color of the electrophoretic particles, although a material for the pigment or the dye is not particularly limited, those which are stably held by the dielectric layer are selected.

[0023] The dielectric layer can be formed on the electrode or the substrate by an ordinary method such as sputtering, vapor deposition, solution coating, solution soaking, spin coating, and Langmuir-Blodgett technique in accordance with the material. The thickness of the dielec-

tric layer is, for example, in a range of several nm to several μm.

[0024] In order to prevent irreversible adsorption of the electrophoretic particles onto the electrode surface and an electrochemical reaction of impurities such as water on the electrode surface, it is desirable that the dielectric layer made of fluorocarbon resin is provided on the surfaces of the second electrode as well as on the first electrode, if required.

[0025] According to the present invention, the covering layer is provided for covering the electrophoretic particles, and consists of a black opaque film, for example, obtained by mixing black carbon powders with plastic. The covering layer is formed by an ordinary method such as vapor deposition or printing. The covering layer contributes to improvement of a contrast of the display apparatus as well as covering the electrophoretic particles.

[0026] According to the present invention, the electric circuit is not particularly limited. For example, an electric circuit can be used, which has a power source with a maximum voltage rating of 100 volts and a power supply capacitance of 10 mA, the polarity thereof being able to be arbitrarily set.

[0027] A state where a display is performed in the electrophoresis display apparatus of the present invention will be briefly described with reference to Figure 1. When a voltage is applied by the electric circuit **10** in such a manner that the first electrode **4** has a polarity different from that of the electrophoretic particles **8**, and the second electrode **5** has the same polarity as that of the electropho-

retic particles 8, the electrophoretic particles 8 move to the dielectric layer 6 covering the first electrode 4 to cover the surface thereof. An observer who is watching the apparatus from outside of the transparent substrate 2 visually recognizes the color of the electrophoretic particles 8. Next, when the polarities of the voltages applied to the first electrode 4 and the second electrode 5 are inverted by the electric circuit 10, the electrophoretic particles 8 move to the dielectric layer 7 covering the second electrode 5 in a region covered with the covering layer 11 to cover the surface thereof. Since the electrophoretic particles 8 are in a region covered with the covering layer 11, an observer visually recognizes the color of the dielectric layer 6, the first electrode 4, or the first substrate 1, i.e., the contrasting color of the electrophoretic particles 8. Depending upon the properties of materials such as the electrophoretic particles 8, the dielectric layer 6 and 7, it is possible to add a memory function so that adsorption of the electrophoretic particles 8 to the dielectric layer 6 or 7 is maintained even in a state where the connection between the power supply circuit 10 and the first electrode 4 and the second electrode 5 is cut after the application of a voltage.

[0028] Hereinafter, the present invention will be described by way of specific embodiments.

First Embodiment

In an electrophoresis display apparatus whose one pixel has a similar structure to that shown in Figure 1, selection, formation, and setting of each member was conducted as follows. As first and second substrates 1 and 2, transparent glass plates with a thickness of 1 mm were used. As a spacer substrate 3, a substrate made of polyimide with a

thickness of 25 μm was used. The gap between the first and second substrates 1 and 2 was prescribed to be 25 μm, and the gap between the spacer substrates 3 was prescribed to be 100 μm. An electrode 4 was produced by vapor-depositing transparent indium oxide to a thickness of about 0.1 μm on the surface of the substrate 1 on a dispersion layer side. An electrode 5 was produced by electrolytically precipitating nickel to a thickness of about 0.1 μm on the surface of the spacer substrate 3 on the dispersion layer side. Dielectric layers 6 and 7 are disposed so as to prevent irreversible adsorption of electrophoretic particles 8 to the first electrode 4 and the second electrode 5, and the dielectric layer 6 is disposed, in particular, so as to have a contrasting color of the electrophoretic particles 8. The dielectric layer 6 was formed to a thickness of about 0.5 μm, using fluorocarbon resin mixed with barium sulfate fine powders. The dielectric layer 7 was formed to a thickness of about 0.5 μm by dip coating transparent fluorocarbon resin. A covering layer 11 was formed by printing a black opaque film obtained by dispersing carbon fine powders in polyester to a thickness of about 10 μm on the surface of the substrate 2 on the opposite side of the dispersion layer. The length of the covering layer 11 from both ends of the substrate 2 was set in such a manner that if all the electrophoretic particles 8 were to adsorb the dielectric layer 7, the covering layer 11 would sufficiently cover them all.

[0029] The dispersion layer was prepared as follows. First, black resin toner (particle diameter: 1 μm) as electrophoretic particles 8 and isopropanol as fluid 9 were mixed so that a mixing weight ratio of the electrophoretic particles 8 became 10%. Furthermore, a trace amount of surfactant was added to the mixture for the purpose of improving dispersion stability, whereby the dispersion layer was

prepared. In this case, the surfaces of electrophoretic particles were negatively charged.

[0030] A driving operation of one pixel in the electrophoresis display apparatus thus obtained will be described below. First, when a D.C. voltage (30 volts) is applied by an electric circuit **10** so that the electrodes **4** and **5** respectively become a positive electrode and a negative electrode, the negatively charged electrophoretic particles **8** move to the dielectric layer **6** covering the electrode **4** to adsorb to the surface thereof. At this time, when the apparatus is observed from the substrate **2** side, the black color of the electrophoretic particles **8** is observed. This state was maintained even after the electrical connection between the electric circuit **10** and the electrode is cut to stop applying a voltage, showing that the display apparatus has a memory function. Next, when a voltage is applied with the polarities being inverted as compared with before, i.e., a D.C. voltage (30 volts) is applied so that the electrode **4** becomes a negative electrode and the electrode **5** becomes a positive electrode, the electrophoretic particles **8** move from the dielectric layer **6** to the dielectric layer **7** covering the electrode **5** to adsorb to the surface thereof. In this case, the surface of the dielectric layer **6** (i.e., a white color) was observed by an observer, and the electrophoretic particles **8** were not observed, as the electrophoretic particles **8** were covered with the mask **11**. Optical reflection characteristics were substantially equal to those of the dielectric layer **6** and the electrophoretic particles **8** themselves, respectively for a white display and a black display, and the display apparatus thus obtained was confirmed to have both brightness and a high contrast, as well as a wide viewing angle intrinsic to the electrophoresis display apparatus.

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[0031] In order to prevent the electrophoretic particles **8** from adhering to the surface of the substrate **1** on the dispersion layer side, it was confirmed to be effective that the surface of the substrate **1** on the dispersion layer side is covered with a dielectric layer made of fluorocarbon resin or the like.

[0032] Second Embodiment

An electrophoresis display apparatus was obtained in the same way as in the first embodiment, except that the following dispersion layer, first electrode, and dielectric layer were used. Herein, titanium oxide (particle diameter: 2 μm) coated with polyethylene as the electrophoretic particles **8** and xylene as the fluid **9** were mixed so that a mixing weight ratio of the electrophoretic particles **8** became 5%. Furthermore, a trace amount of surfactant was added to the mixture for the purpose of improving dispersion stability, whereby the dispersion layer was prepared. In this case, the surfaces of the electrophoretic particles were positively charged. Furthermore, a platinum/platinum black electrode was used as the first electrode **4**, and transparent fluorocarbon resin was used as the dielectric layer **6** covering the first electrode **4**. The other components have the same structure as that in the first embodiment.

[0033] Hereinafter, an operation of one pixel in the electrophoresis display apparatus in the second embodiment will be described. When a D.C. voltage (20 volts) is applied by an electric circuit **10** so that the first electrode **4** and the second electrode **5** respectively become a positive electrode and a negative electrode, the positively charged electrophoretic particles **8** move to the dielectric layer **6** covering the electrode **4** to adsorb to the surface thereof. At

this time, when the apparatus is observed from the second substrate 2 side, the white color of the electrophoretic particles 8 is observed. This state is maintained even after the electrical connection between the electric circuit 10 and the electrode is cut to stop applying a voltage, showing that the display apparatus has a memory function. Next, when a voltage is applied with the polarities being inverted compared with before, i.e., a D.C. voltage (20 volts) is applied so that the first electrode 4 becomes a positive electrode and the second electrode 5 becomes a negative electrode, the electrophoretic particles 8 move from the dielectric layer 6 to the dielectric layer 7 covering the electrode 5 to adsorb to the surface thereof. In this case, the surface of the first electrode 4 (i.e., a black color) is observed by an observer through the transparent dielectric layer 6, and the electrophoretic particles 8 are not observed, as the electrophoretic particles 8 are covered with the covering layer 11. Optical reflection characteristics were substantially equal to those of the electrophoretic particles 8 and the electrode 4 themselves, respectively for a white display and a black display, and the display apparatus thus obtained was confirmed to have both brightness and a high contrast, as well as a wide viewing angle intrinsic to the electrophoresis display apparatus.

[0034] Third Embodiment

An electrophoresis display apparatus was obtained in the same way as in the first embodiment, except for a dispersion layer, a dielectric layer, and a first substrate 1. Herein, titanium oxide (particle diameter: 2 μm) coated with polyethylene as the electrophoretic particles 8 and xylene as the fluid 9 were mixed so that a mixing weight ratio of the electrophoretic particles 8 became 5%. Furthermore, a trace amount of surfactant was added to the mixture for the

purpose of improving dispersion stability, whereby the dispersion layer was prepared. In this case, the surfaces of the electrophoretic particles were positively charged. As the dielectric layer **6** covering the first electrode **4**, transparent fluorocarbon resin was used. Furthermore, black glass in which a black pigment was dispersed was used as the first substrate **1**.

[0035] Hereinafter, a driving operation of one pixel in the electrophoresis display apparatus will be described. A D.C. voltage (20 volts) is applied by an electric circuit **10** so that the first electrode **4** and the second electrode **5** respectively become a negative electrode and a positive electrode. The positively charged electrophoretic particles **8** move to the dielectric layer **6** covering the first electrode **4** to adsorb to the surface thereof. At this time, when the apparatus is observed from the second substrate **2** side, the white color of the electrophoretic particles **8** is observed. Next, when a voltage is applied with the polarities being inverted compared with before, i.e., a D.C. voltage (20 volts) is applied so that the first electrode **4** becomes a positive electrode and the second electrode **5** becomes a negative electrode, the electrophoretic particles **8** move from the dielectric layer **6** to the dielectric layer **7** covering the second electrode **5** to adsorb to the surface thereof. In this case, the surface of the substrate **1** (i.e., a black color) is observed by an observer through the transparent dielectric layer **6** and the transparent electrode **4**, and the electrophoretic particles **8** are not observed, as the electrophoretic particles **8** are covered with the covering layer **11**. Optical reflection characteristics were substantially equal to those of the electrophoretic particles **8** and the substrate **1** themselves, respectively for a white display and a black display, and the display apparatus thus obtained

was confirmed to have both brightness and a high contrast, as well as a wide viewing angle intrinsic to the electrophoresis display apparatus.

[0036] Fourth Embodiment

Figure 2 is a cross-sectional view showing a structure of one pixel portion of another electrophoresis display apparatus of the present invention. Hereinafter, the structure of the fourth embodiment will be described with reference to Figure 2. In the same way as in the first embodiment, in the pixel portion shown in Figure 2, the dispersion layer consisting of the transparent fluid **9** containing the electrophoretic particles **8** is held in space surrounded by the first substrate **1**, the transparent second substrate **2**, and the spacer substrate **3** for fixing a distance between two substrates. The first electrode **4**, the second electrode **5**, and a transparent third electrode **21** are disposed respectively on the surfaces of the first substrate **1**, the spacer substrate **3**, and the second substrate **2** on the dispersion layer side. The surfaces of the first electrode **4**, the second electrode **5**, and the third electrode **21** are respectively covered with the dielectric layers **6**, **7**, and **22**, and the dielectric layer **6** has a contrasting color of the electrophoretic particles **8**. The electric circuit **10** is provided so as to apply a voltage to the dispersion layer through the third electrode **21**, and the dielectric layers **6**, **7**, and **22**.

[0037] The third electrode **21** is disposed to allow the electrophoretic particles **8** to smoothly move between the surfaces of the dielectric layers **6** and **7**. By applying an electric potential with a polarity opposite to that of the electrophoretic particles **8** to the third electrode **21**, the electrophoretic particles **8** can be moved smoothly between the surfaces of the dielectric layers **6** and **7**, and a nonuni-

form display can be reduced. The covering layer 11 is provided to cover the electrophoretic particles 8 in the case where the electrophoretic particles 8 are positioned at the surface of the dielectric layer 7. The covering layer 11 is formed on the outer surface of the second substrate 2 so as to sufficiently cover the spacer substrate 3 and the second electrode 5. An observer observes the display apparatus from the substrate on the opposite side of the dispersion layer.

[0038] The detail of each portion of the electrophoresis display apparatus having the above-mentioned structure is as follows. Transparent glass with a thickness of 1 mm was used as the first substrate 1 and the second substrate 2. A substrate made of glass epoxy resin with a thickness of 50 μm was used as the spacer substrate 3. The gap between the first and second substrates 1 and 2 was prescribed to be 50 μm, and the gap between the spacer substrates 3 was prescribed to be 150 μm. The first electrode 4 and the third electrode 21 were produced by vapor-depositing transparent indium oxide to a thickness of about 0.1 μm on the surfaces of the first substrate 1 and the second substrate 2, respectively. The electrode 5 was produced by electrolytically precipitating nickel to a thickness of about 0.1 μm on the surface of the spacer substrate 3 on the dispersion layer side. The dielectric layers 6, 7, and 22 were disposed so as to prevent irreversible adsorption of the electrophoretic particles 8 to the first electrode 4, the second electrode 5, and the third electrode 21, and the dielectric layer 6 was disposed, in particular, so as to have white color contrasted with the color of the electrophoretic particles 8. The dielectric layer 6 was formed to a thickness of about 0.5 μm by spin coating, using fluorocarbon resin mixed with titanium oxide fine powders. The dielectric layer 22 was

formed to a thickness of about 0.5 μm by the same method as that of the dielectric layer 6, using transparent fluorocarbon resin. Furthermore, the dielectric layer 7 was formed to a thickness of 0.5 μm by dip coating a transparent fluorocarbon resin. The covering layer 11 was formed by printing a black opaque film obtained by dispersing carbon fine powders in polyester to a thickness of about 10 μm on the outer surface of the second substrate 2. The width and position of the covering layer 11 was set in such a manner that in the case where all the electrophoretic particles 8 adsorb to the dielectric layer 7, the covering layer 11 can sufficiently cover them. The dispersion layer was formed in the same way as in the first embodiment.

[0039] Hereinafter, a driving operation of one pixel in the electrophoresis display apparatus thus constructed will be described. A D.C. voltage (50 volts) is applied by an electric circuit 10 so that the first electrode 4, the second electrode 5, and the third electrode 21 respectively become a positive electrode, a negative electrode, and a negative electrode. The negatively charged electrophoretic particles 8 move to the dielectric layer 6 covering the electrode 4 to adsorb to the surface thereof. At this time, when the apparatus is observed from the second substrate 2 side, the black color of the electrophoretic particles 8 is observed. This state was maintained even after the electrical connection between the electric circuit 10 and the electrode is cut to stop applying a voltage, showing that the display apparatus has a memory function. Next, when a voltage is applied with the polarities of the first electrode 4 and the second electrode 5 being inverted compared with before, i.e., a D.C. voltage (50 volts) is applied so that the first electrode 4, the second electrode 5, and the third electrode 21 respectively become a negative electrode, a

positive electrode, and a negative electrode, the electrophoretic particles 8 move from the dielectric layer 6 to the dielectric layer 7 covering the second electrode 5 to adsorb to the surface thereof. In this case, the surface of the dielectric layer 6 (i.e., a white color) is observed by an observer, and the electrophoretic particles 8 are not observed, as the electrophoretic particles 8 are covered with the covering layer 11. Optical reflection characteristics were substantially equal to those of the dielectric layer 6 and the electrophoretic particles 8 themselves, respectively for a white display and a black display, and the display apparatus thus obtained was confirmed to have both brightness and a high contrast, as well as a wide viewing angle intrinsic to the electrophoresis display apparatus.

[0040] Fifth Embodiment

An electrophoresis display apparatus was obtained in the same way as in the fourth embodiment, except for the following alterations of the dispersion layer and the dielectric layer 6. Herein, Dially ride yellow (particle diameter: 0.2 μm) was used as the electrophoretic particles 8, and a 7:3 mixture of perchloroethylene and xylene was used as the fluid 9. The electrophoretic particles and the fluid 9 were mixed so that a mixing weight ratio of the electrophoretic particles 8 became 2%. Furthermore, a trace amount of surfactant was added to the mixture for the purpose of improving dispersion stability, whereby the dispersion layer was prepared. In this case, the surfaces of the electrophoretic particles were negatively charged. As the dielectric layer 6, fluorocarbon resin in which carbon fine powders were dispersed was used. In this case, a display of yellow color and black color is obtained.

[0041] Sixth Embodiment

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Figure 3 is a view illustrating a structure of one embodiment of an electrophoretic display apparatus according to the present invention. In the electrophoretic apparatus according to the present invention, a plurality of structures of one pixel shown in Figures 1 and 2 are provided. Such an electrophoresis apparatus mainly includes, for example, as shown in Figure 3, a first glass substrate 32 on which various electrodes are formed, a dielectric layer 34, a mesh electrode 33 with a thickness of 25 µm including a plurality of rectangular dot-shaped openings, each having a size of about 150 × 150 µm, and a second glass substrate 42 having a mask 31 as a covering layer, disposed on top of another in this order, in which a dispersion layer (not shown) is sealed in each opening of the mesh electrode 33 and each region defined by the first glass substrate and the second glass substrate. The mesh electrode 33 is a common electrode, and an inside surface of each opening is covered with a dielectric layer. A scanning electrode group 35 corresponding to the mesh electrode 33, and a signal electrode group 36 are formed on the first substrate. Furthermore, in order to perform active matrix driving, pixel electrodes 38 as first electrodes and thin film transistors 37 are formed on the first substrate so as to correspond to the openings of the mesh electrodes 33. The dielectric layer 34 has a contrasting color of electrophoretic particles in the dispersion layer. The mask 31 is formed in such a manner that in the case where the electrophoretic particles adsorb to the inner surface of each opening of the mesh electrode 33, the electrophoretic particles are sufficiently covered, while an aperture ratio becomes as high as possible. The openings of the mask 31 correspond to those of the mesh electrode 33.

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[0042] Any of the first to fifth embodiments is applicable to the electrophoretic display apparatus shown in Figure 3. Driving of each pixel is controlled by the scanning electrode group and the signal electrode group which receives an image signal. An observer observes the display apparatus from the mask 31 side. For example, the case where the members described in the first embodiment are used so as to have a color which forms a contrast with that of the dispersion layer and the electrophoretic particles will be described. In this case, the electrophoretic particles are negatively charged. Under the condition that the mesh electrode 33 was provided and a voltage was applied so that a pixel voltage became + 30 volts, the electrophoretic particles covered the dielectric layer 34 covering the pixel electrode, so that a pixel exhibited a display of black color which is the color of the electrophoretic particles. On the other hand, under the condition that the mesh electrode was provided, and a voltage was applied so that a pixel voltage became -30 volts, the electrophoretic particles adsorbed to the surface of the mesh electrode and covered with the mask 31, so that a pixel exhibited a display of white color which is the color of the dielectric layer covering the pixel electrode. Furthermore, both the black display and the white display were maintained even after the application of a voltage was stopped, and it was confirmed that the display apparatus has a memory function.

[0043]

[Effect of the Invention] As described above in detail, in the display apparatus of the present invention, electrophoretic particles are dispersed in colorless fluid containing no coloring matter material, and a member other than the fluid has a contrasting color of the electrophoretic particles. Therefore, unlike the conventional example,

a coloring matter material does not enter and adsorb to the electrophoretic particles, transparent electrodes or the like, and an electrophoresis display apparatus which achieves both brightness and a high contrast can be provided.

[Brief Description of the Drawings]

[Figure 1] A cross-sectional view showing a structure of one pixel in one embodiment of a display apparatus according to the present invention.

[Figure 2] A cross-sectional view showing a structure of one pixel in another embodiment of the display apparatus according to the present invention.

[Figure 3] A view illustrating an entire structure of the electrophoresis display apparatus according to the present invention.

[Description of the Reference Numerals]

1, 2 ... substrate
3 ... spacer substrate
4, 5 ... electrode
6, 7, 34 ... dielectric layer
8 ... electrophoretic particle
9 ... transparent fluid
10 ... electric circuit
11 ... covering layer
21 ... electrode
22 ... dielectric layer
31 ... mask
32, 42 ... glass substrate
33 ... mesh electrode
35 ... scanning electrode group
36 ... signal electrode group

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37 ... thin film transistor

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[Abstract]

[Problem] An electrophoresis display apparatus, which can achieve both brightness and a high contrast, is obtained.

[Means for Solving the Problem] Using a dispersion layer containing colorless fluid and electrophoretic particles, a first electrode and/or a member having a color which can form a contrast with the electrophoretic particles are/is formed in a region which can be seen by a user, and a second electrode is formed in a region which cannot be seen by the user.

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[Name of the Document] ABSTRACT

[Abstract]

[Objective] An objective of the present invention is to provide a method for measuring migration time which is capable of minimizing deterioration due to electrode reactions or electrolysis without lowering contrast.

[Structure] The time required for pigment **13b** in an electrophoresis display device **2** to move is measured in terms of saturation time of luminance. A voltage application time control apparatus **4**, whose drive voltage application time is set to the luminance saturation time, is provided in the electrophoresis display apparatus. Alternatively, a sensor **21** capable of detecting the luminance of the electrophoresis display device **2** is provided, with a voltage application control means capable of terminating drive voltage application when the output of the sensor **21** has reached a sensor output corresponding to a previously measured saturation value of luminance.

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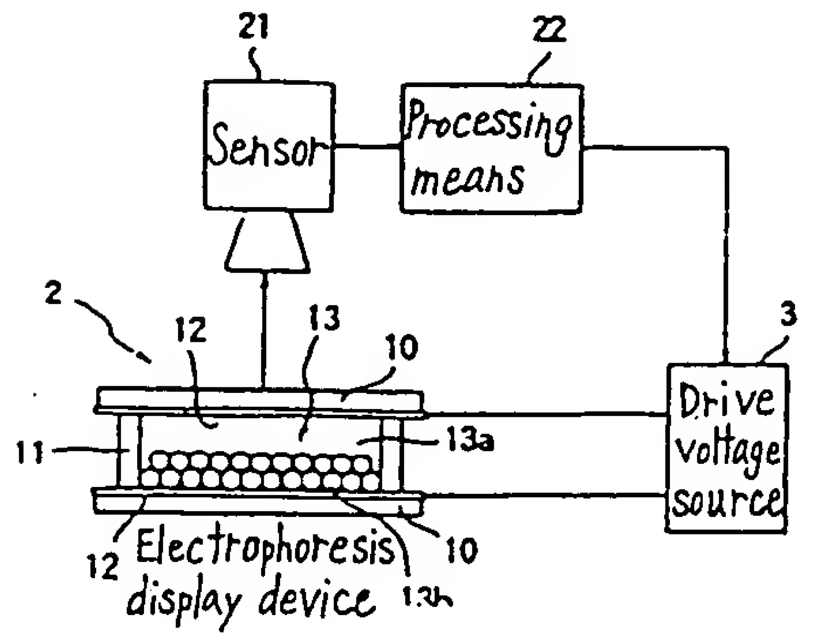
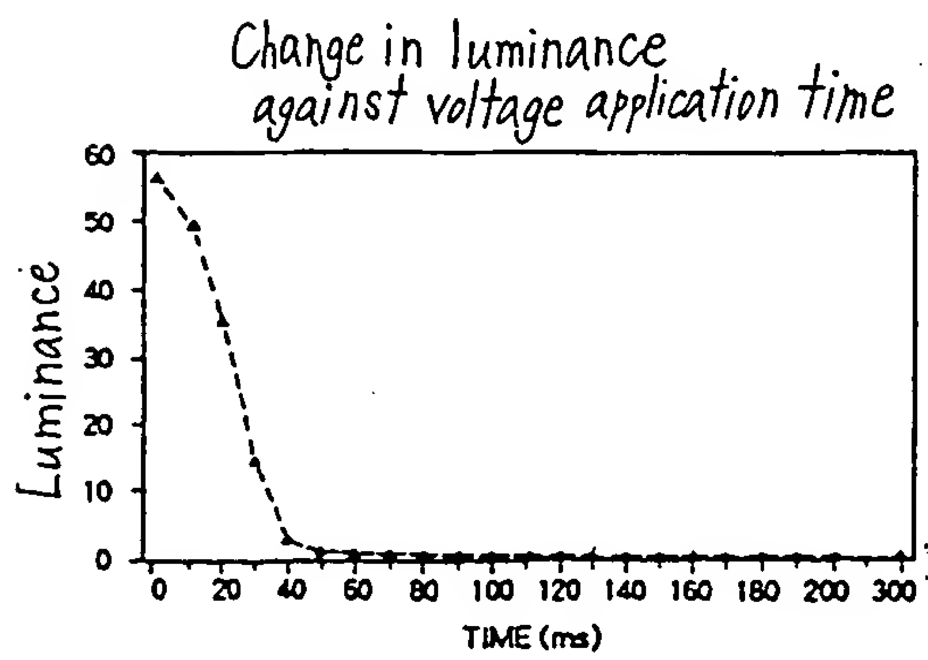
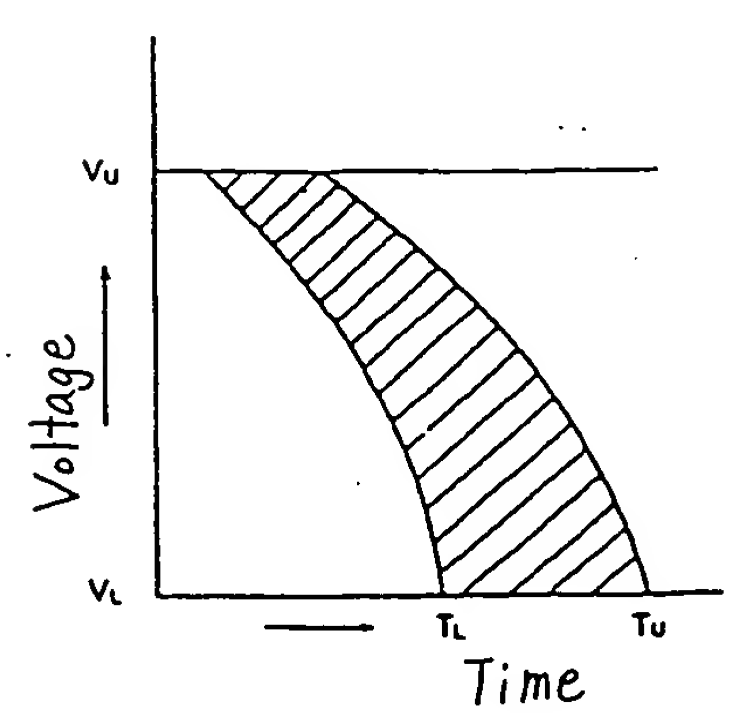
[Fig. 1]



[Fig. 2]



[Fig. 3]



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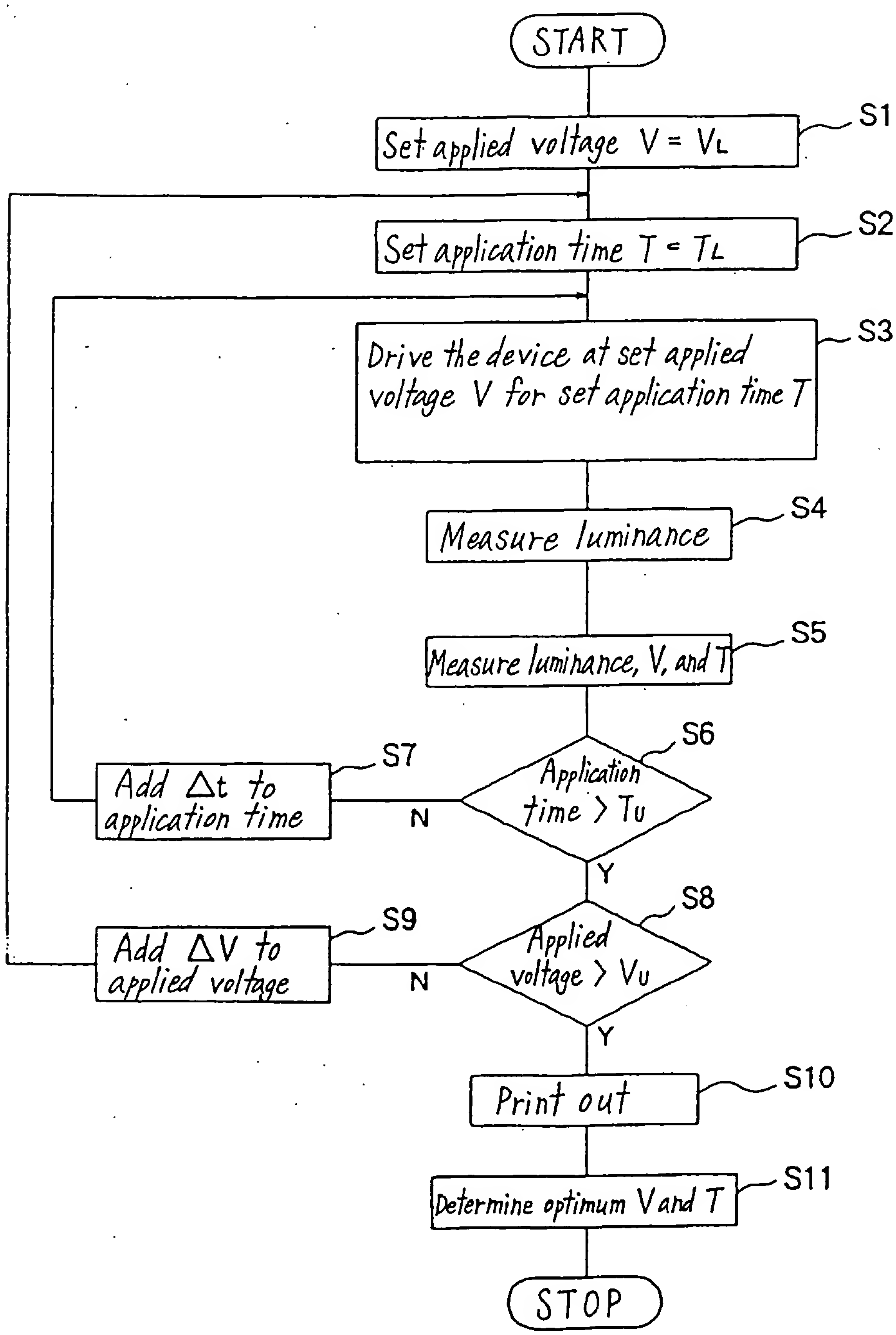
(Fig. 4)



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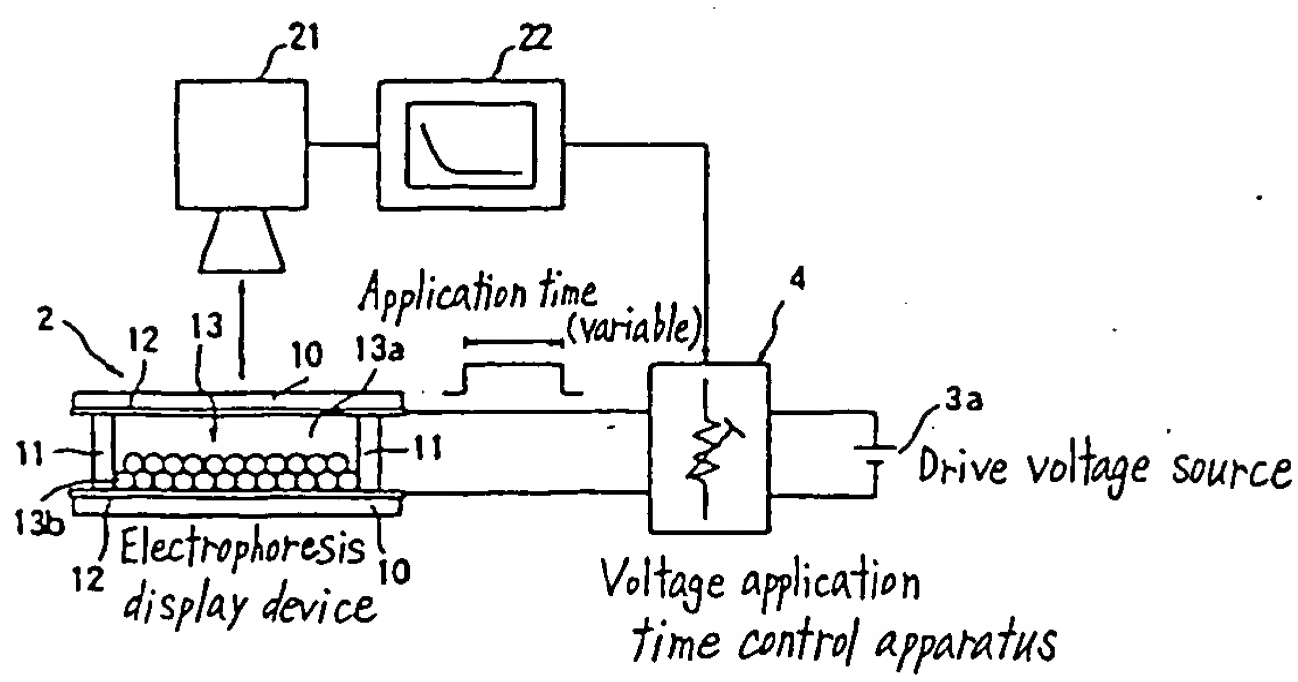
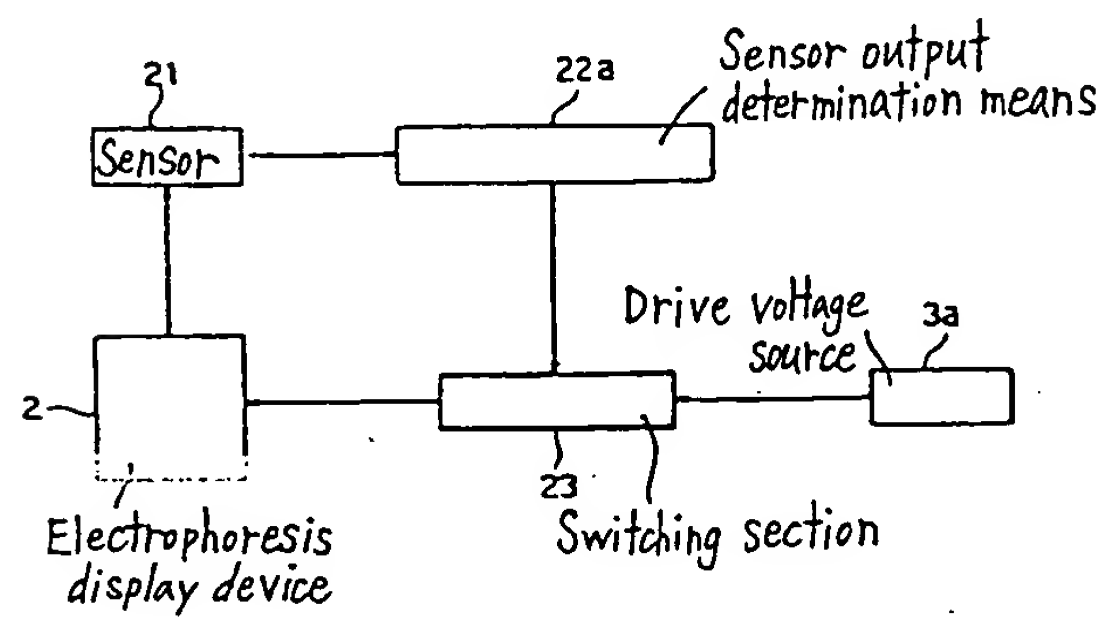
(Fig. 5)



(Fig. 6)



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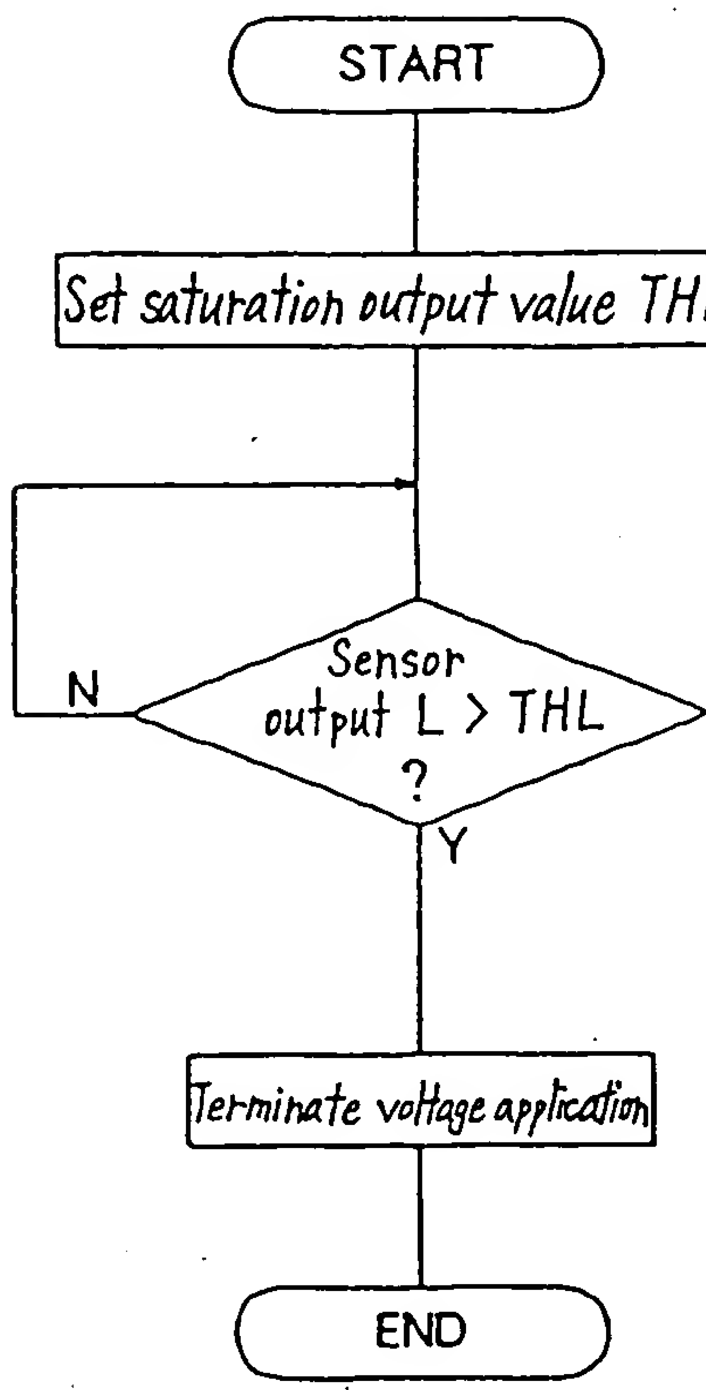
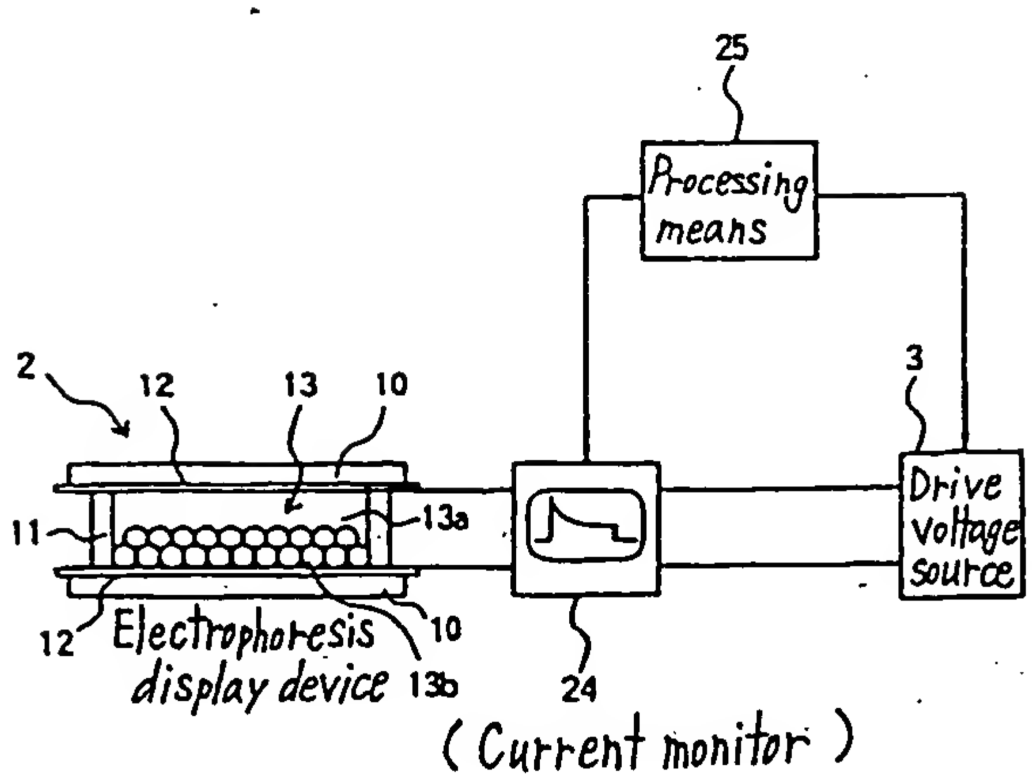
(Fig. 7)



(Fig. 8)



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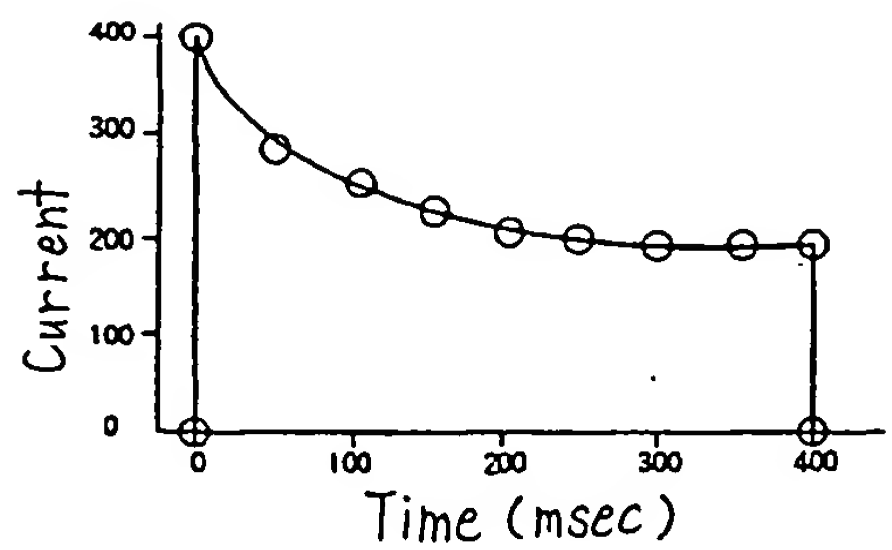
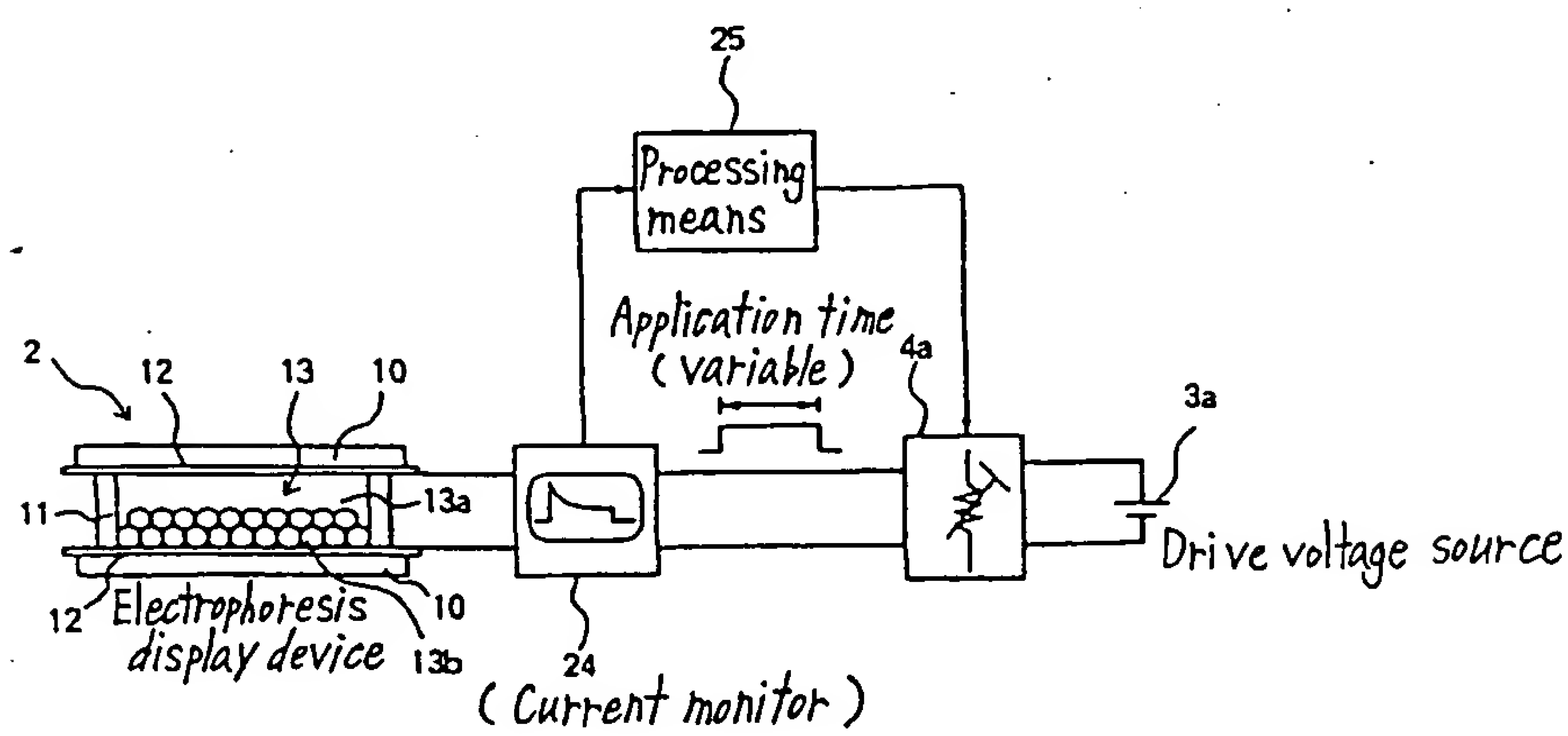
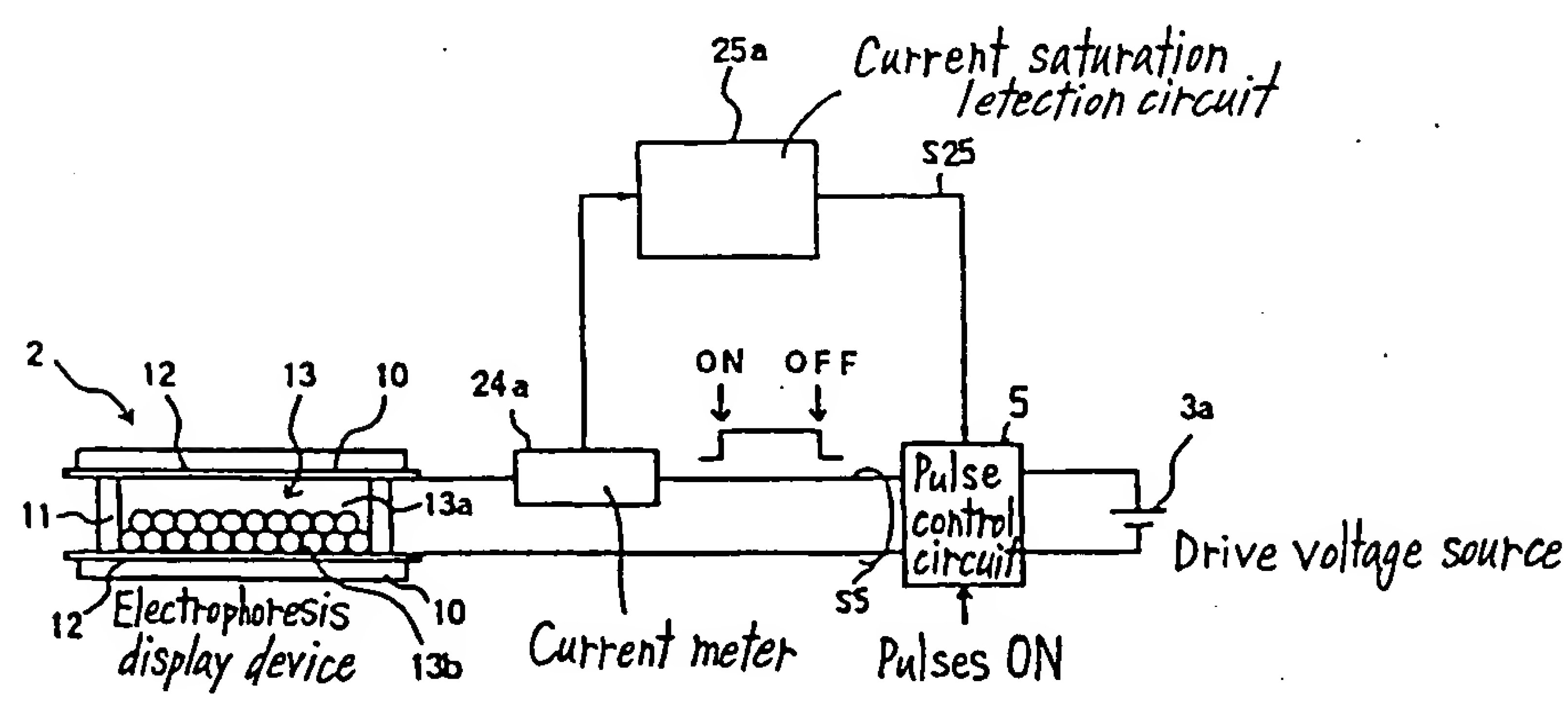
[Fig. 9]



[Fig. 11]



[Fig. 12]



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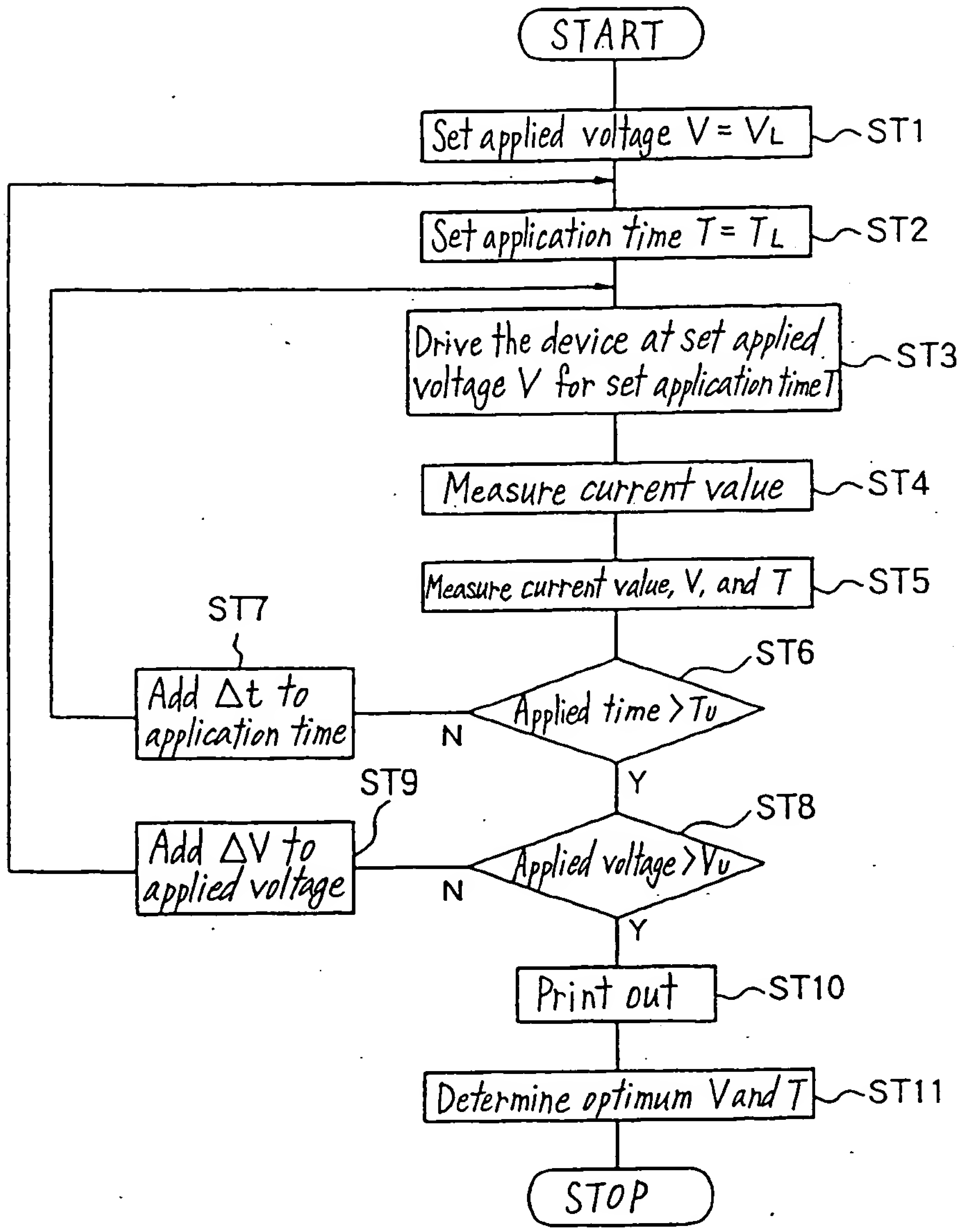
[Fig. 10]



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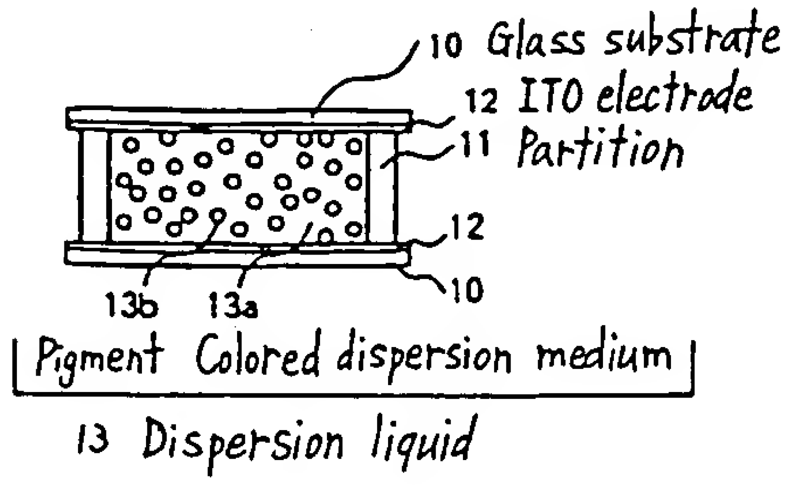
[Fig. 13]



[Fig. 14]